Ball Aerospace & Technologies Corp.

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9 October 2003
Defsys.03.SMF.043

Northrop Grumman Corporation
Space Technology
One Space Park, M/S R10/2077G
Redondo Beach, CA 90278

Attention: Ms. Fayda Ayache
               Subcontracts Manager

Subject: Request to Disclose OMPS Related Data

Reference: Subcontract 64584DDQ2S

In accordance with referenced subcontract, Ball Aerospace respectfully requests your authorization our subcontractor, Raytheon, to present OMPS related data at the Fall 2003 AGU conference. This specific request is for the attached presentation "*The Ozone Mapping and Profiler Suite: The Extension of the BUV Technique to Meet Future Ozone MeasurementRequirements*".

The presentation is due no later than 1 DEC 2003 and would appreciate your decision before that time. Please contact me at 303/939-4373 or e-mail at sflahert@ball.com if I can provide any additional information.

Sincerely,

Sean M. Flaherty, CPCM
Contracts Manager
Ball Aerospace & Technologies Corp.

Space & Electronics
Clearance Request for Public Release of Information

NORTHROP GRUMMAN
Space Technology

ALLOW 3-6 WEEKS FOR CUSTOMER/GOVERNMENT REVIEW

☐ ABSTRACT /SUMMARY ☐ MEDIA MATERIALS
☒ TECHNICAL PAPER ☐ ADVERTISEMENT
☐ ORAL PRESENTATION ☐ BROCHURE
☐ NEWS RELEASE ☐ AUDIOVISUAL
☐ EXHIBIT DISPLAY ☐ INTERNET MATERIAL

1. AUTHOR(S)	CCC	BLDG	MAIL STA	PHONE	PROCESS ORGANIZATION /PROGRAM
Raytheon as subcontractor to Ball Aerospace & Technologies Corp. (BATC)	M294	R10	2744	X.46806	P&SCM/NPOESS

2. TITLE OF MATERIAL	3. AUTHOR(S) DEADLINE
The Ozone Mapping and Profiler Suite: The Extension of the BUV Technique to Meet Future Ozone Measurement	1 DEC 2003

4. ☐ COMPANY FUNDED ☐ NON-GOVERNMENT CONTRACT ☒ GOVERNMENT CONTRACT

CLASSIFICATION OF MATERIAL: ☒ UNCLASSIFIED ☐ U.S. ONLY ☐ SECRET

5. SESSION CLASSIFIED YES ☐ NO ☒
DISTRIBUTE OUTSIDE U.S.? YES ☐ NO ☒

6. PURPOSE: FOR MEETINGS / CONFERENCES LIST NAME, SPONSOR, DATE, LOCATION. FOR PUBLICATIONS, LIST JOURNAL, PUBLISHER, PROPOSED DATE.
To allow subject presentation to be provided to the AGU Fall meeting.

7. DOES THE SUBMITTED MATERIAL DESCRIBE AN INVENTION, SOFTWARE OR CONCEPT THAT IS POTENTIALLY PATENTABLE? IF DEVELOPED UNDER IR&D, LIST PROJECT NUMBER: — YES ☐ NO ☒

8. IF YES TO 7, HAS AN INVENTION DISCLOSURE, FORM 125, BEEN FILED WITH LAW DEPARTMENT? IF ANSWER IS YES, LIST DISCLOSURE DOCKET NUMBER: PATENT NUMBER: — YES ☐ NO ☐

9. WAS ANY WORK DESCRIBED DONE UNDER CONTRACT? (IF SO, COMPLETE 10, 11, AND 12.) — YES ☒ NO ☐

10. CONTRACT NUMBER: F0470-02-C-0502 SALES NUMBER: 01E163

11. PROCURING AGENCY / PRIME CONTRACTOR: NPOESS Integrated Program Office (IPO)/Northrop Grumman Space Technology (NGST)

12. CUSTOMER TECHNICAL MONITOR(S): Lt. Curtis Stutz PHONE NUMBER(S): (301) 713-4783

13. AUTHOR'S SIGNATURE (ON BEHALF OF AUTHORS)
SIGNATURE _____
TYPED NAME: BATC DATE _____

14. ORGANIZATION/PROGRAM DESIGNEE
SIGNATURE _____
TYPED NAME: F. Ricker or Designee DATE _____

15. BUSINESS DEVELOPMENT (REQUIRED FOR NEWS RELEASES AND ADVERTISEMENTS ONLY)
SIGNATURE _____
TYPED NAME: DATE _____

16. LAW DEPARTMENT (REQUIRED IF ANSWER TO 7 OR 8 ABOVE IS "YES")
SIGNATURE _____
TYPED NAME: DATE _____

17. EXPORT (AUDIENCE MAY INCLUDE NON-U.S.PERSONS)
SIGNATURE _____
TYPED NAME: BATC DATE _____

18. SECURITY
SIGNATURE _____
TYPED NAME: N. Gimma DATE _____

19. TECHNOLOGY CLEARANCE OFFICE
SIGNATURE _____
TYPED NAME: S. L. Cohen DATE _____

CLEARANCE: ☐ APPROVED ☐ APPROVED W/AMENDMENTS ☐ DENIED ☐ LIMITED APPROVAL
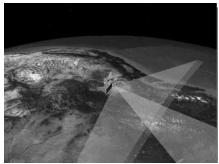
20. INSTRUCTIONS / REMARKS
Concurrence:

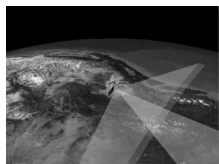Nann Gimma
NPOESS Security Manager

The Ozone Mapping and Profiler Suite: The Extension of the BUV Technique to Meet Future Ozone Measurement Requirements

Colin J. Seftor, Jack C. Larsen

Raytheon Information Technology and Scientific Services

Quinn Remund, Juan V. Rodriguez

Ball Aerospace & Technologies Corp.

Lawrence E. Flynn

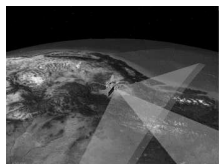**NOAA / NESDIS**

Ernest Hilsenrath

NASA Goddard Space Flight Center

Introduction

**First scheduled flight is on the NPOESS Preparatory Project (NPP) mission in 2006**

- **The Ozone Mapping and Profiler Suite (OMPS) is the next-generation ozone monitoring system designed to replace both the Total Ozone Mapping Spectrometer (TOMS) and Solar Backscatter Ultraviolet Spectrometer/2 (SBUV/2) systems**
  - **OMPS will fly onboard the National Polar-orbiting Operational Environmental Satellite System (NPOESS)**

Both the nadir mapper and nadir/limb profiler system will provide measurements with higher accuracy and precision than heritage

- **The OMPS nadir mapper will extend the nearly 3 decade data set of total column ozone measurements taken by the TOMS series of instruments**
- **The OMPS nadir profiler/limb profiler system will extend the nearly 3 decade data set of ozone profiler measurements taken by the SBUV, SBUV/2 series of instruments**
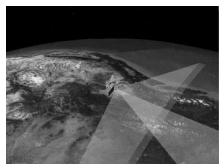
Nadir Sensor Consists of a Mapper and a Co-Boresighted Profiler

- **Single pushbroom telescope**
- **Two grating spectrometers**
  - **Each spectrometer has a CCD detector array**
  - **Both sample spectrum at 0.42 nm, 1 nm FWHM end-to-end resolution**
- **Calibration stability maintained by periodic solar observations using dual reflective diffusers**
- **Electronics**
  - **CCD preamplifier electronics in sensor housing**
  - **Main electronics box**
    - ◆ **Analog-to-digital conversion**
    - ◆ **On-orbit pixel corrections**

Telescope and Calibration Mechanism

**Total Column Spectrometer**

Nadir Profile Spectrometer
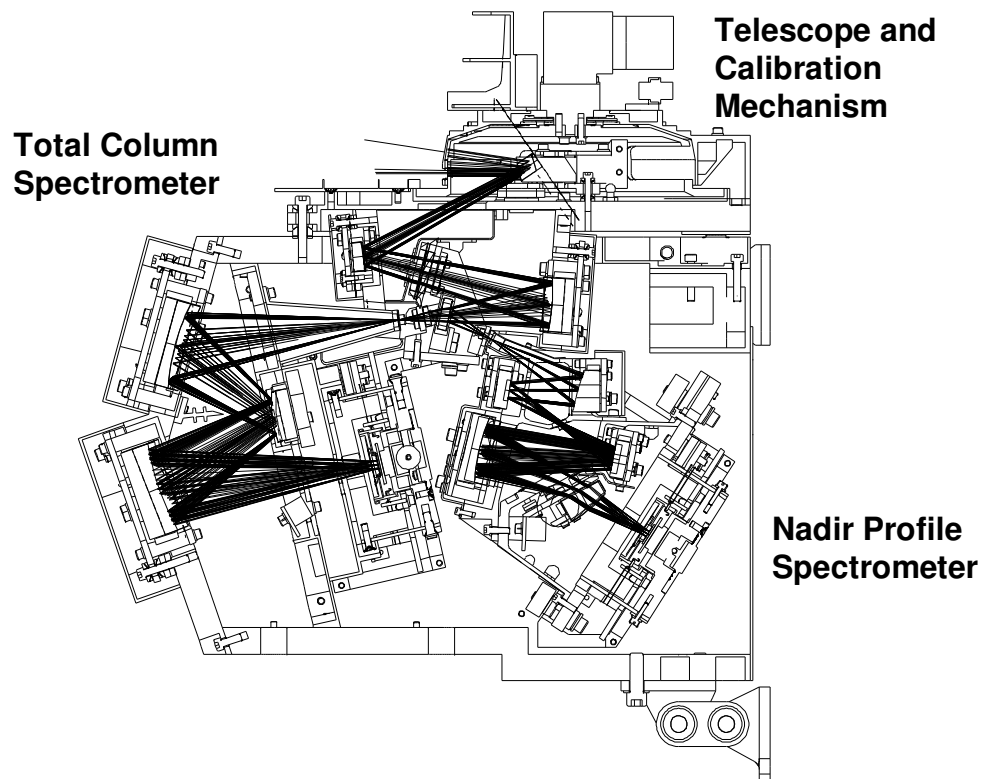
Nadir total column has 300-380 nm coverage
Nadir profiler has 250-310 nm coverage

Nadir Sensor Fields of View

- **Total Column:**
  - **110° cross-track FOV, 0.27 ° along-track slit width, 8.5 ° FOV curvature on Earth**
  - **35 cross-track bins: 3.35 ° (50 km) at nadir, 2.84 ° at ±55 °**
  - **50 km along-track resolution at nadir (7.6 sec reporting period)**
- **Nadir Profile:**
  - **16.6° cross-track FOV, 0.26° along-track slit width**
  - **One 250 km cell cross-track**
  - **250 km along-track resolution (38 sec reporting period)**

*The Ozone Mapping and Profiler Suite*
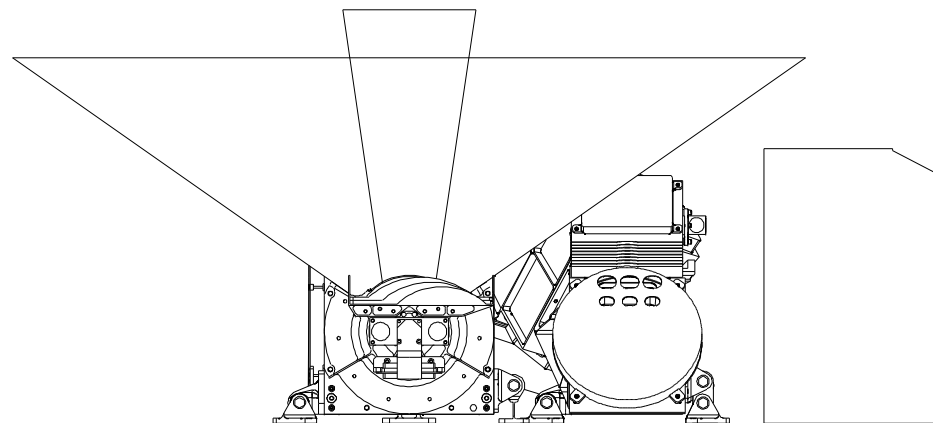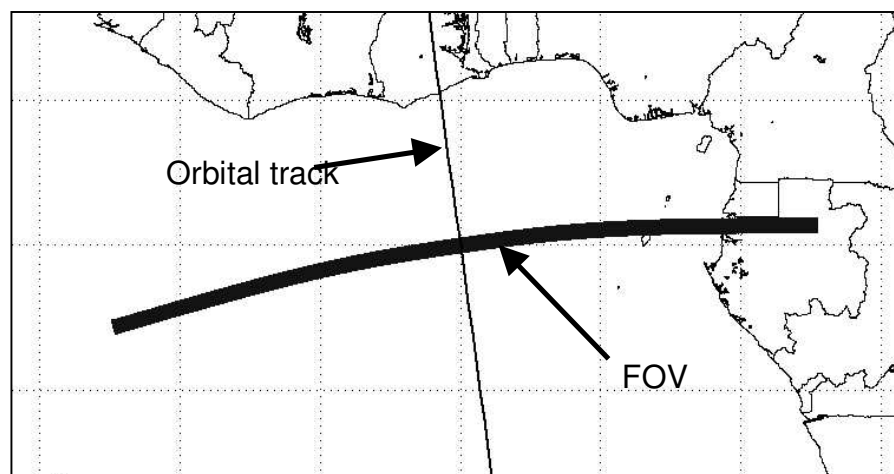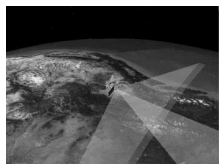
OMPS Total Column Algorithm Builds on the Strong Foundation of TOMS Version 7
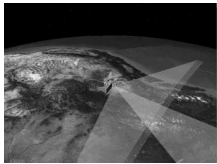
- **Version 7 TOMS algorithm retrieves total column ozone with close to threshold performance**

  - **Uses logarithm of the ratio of backscattered radiance to incident solar irradiance, N**

  - **Assumes change in N value linear with wavelength**

  - **Uses a wavelength triplet**
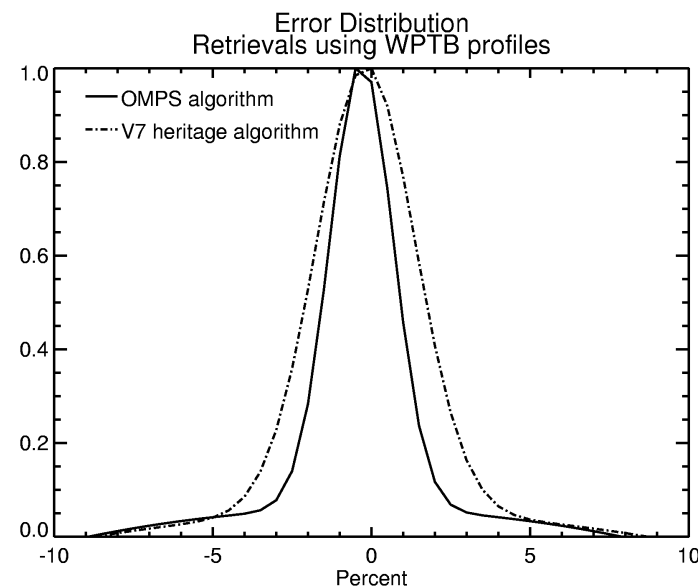
- **Enhancements bring OMPS algorithm performance to within NPOESS requirements**

  - **Multiple triplets**

  - **Temperature-insensitive wavelengths**

 - **Temperature and ozone profile corrections**

  - **Tropospheric residual**

Error Distribution
Retrievals using WPTB profiles

Legend: OMPS algorithm; V7 heritage algorithm. Y-axis 0.0 to 1.0, X-axis Percent -10 to 10.

Limb Sensor Measures Limb Scatter in the Ultraviolet, Visible, and Near-Infrared

MPS NPOESS

- **Six apertures, three slits, one prism, one focal plane**
  - **Two types of raw data records corresponding to different integration times**
  - **Bandpass varies from 2.5 to 50 nm over 290-1000 nm**
- **Calibration stability maintained by periodic solar observations using dual transmissive diffusers**
- **Electronics similar to nadir Limb scatter flight heritage:**
  - **Solar Mesosphere Explorer (SME)**
  - **Shuttle Ozone Limb Sounding Experiment / Limb Ozone Retrieval Experiment (SOLSE/LORE) on STS-87 (December 1997)**

Limb Radiance Profiles for M325 Ozone Profile, SZA=40°

Legend:
- 290 nm
- 350 nm
- 600 nm
- 1000 nm

Y-axis: Altitude (km)
X-axis: Radiance (W/m^2/sr/nm)
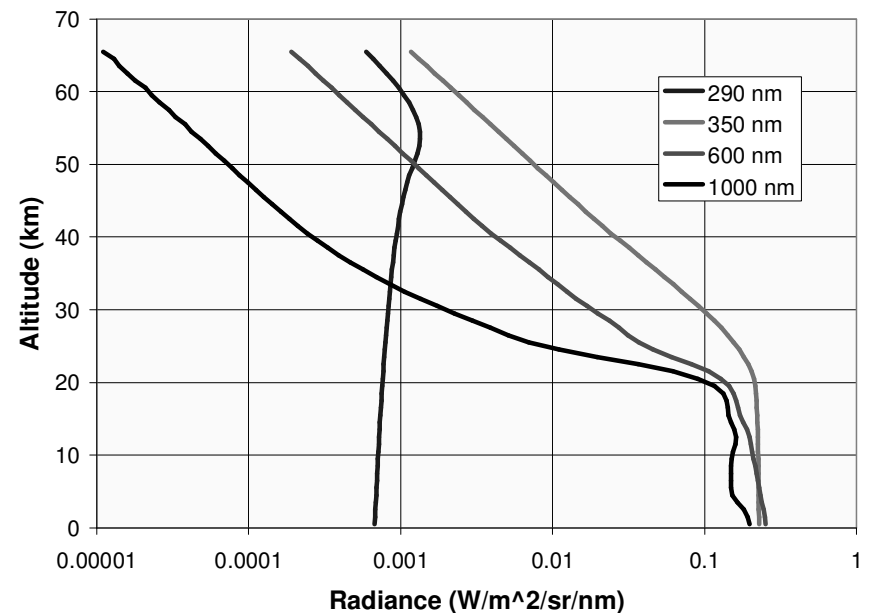
Remote Sensing of Limb-Scattered Solar Radiation Shares Atmospheric Radiative Transfer Physics, Calibration Techniques with OMPS Nadir Sensor
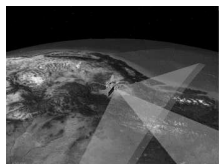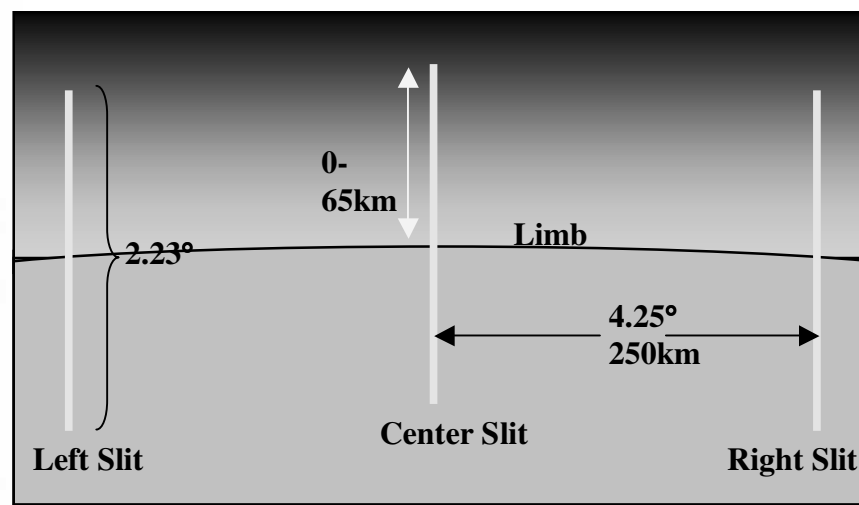
# OMPS Limb Sensor Stares at the Limb Along the Satellite Track

Photo from GSFC's SOLSE/LORE Shuttle flight
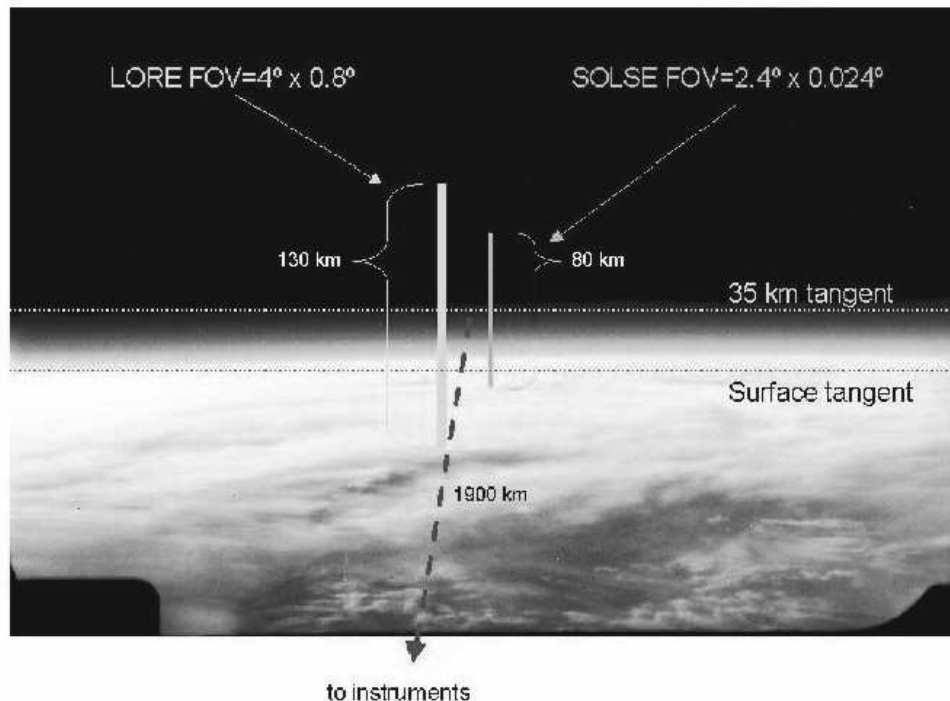
OMPS limb sampling (worst case pointing limit)

- **OMPS limb sensor has 3 slits separated by 4.25 degrees**
- **38 second reporting period: 250 km along track**
- **130 km (2.23 degree) vertical FOV at limb for 0-60 km coverage plus offsets (pointing, orbital variation, Earth oblateness)**
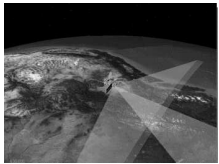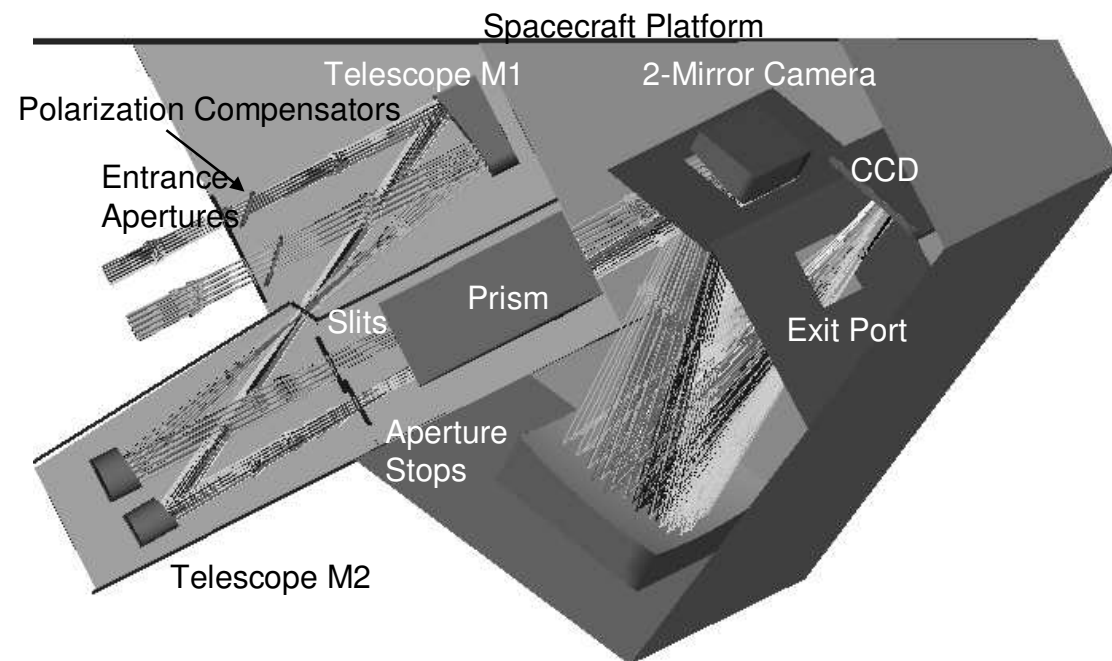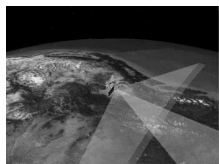
Optical Design

- ● **Prism spectrometer**
  - – **290-1000 nm**
  - – **Spectral resolution matched to ozone absorption features**
  - – **Polarization compensators minimize sensor polarization sensitivity**
  - – **Low stray light**
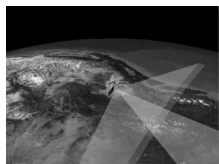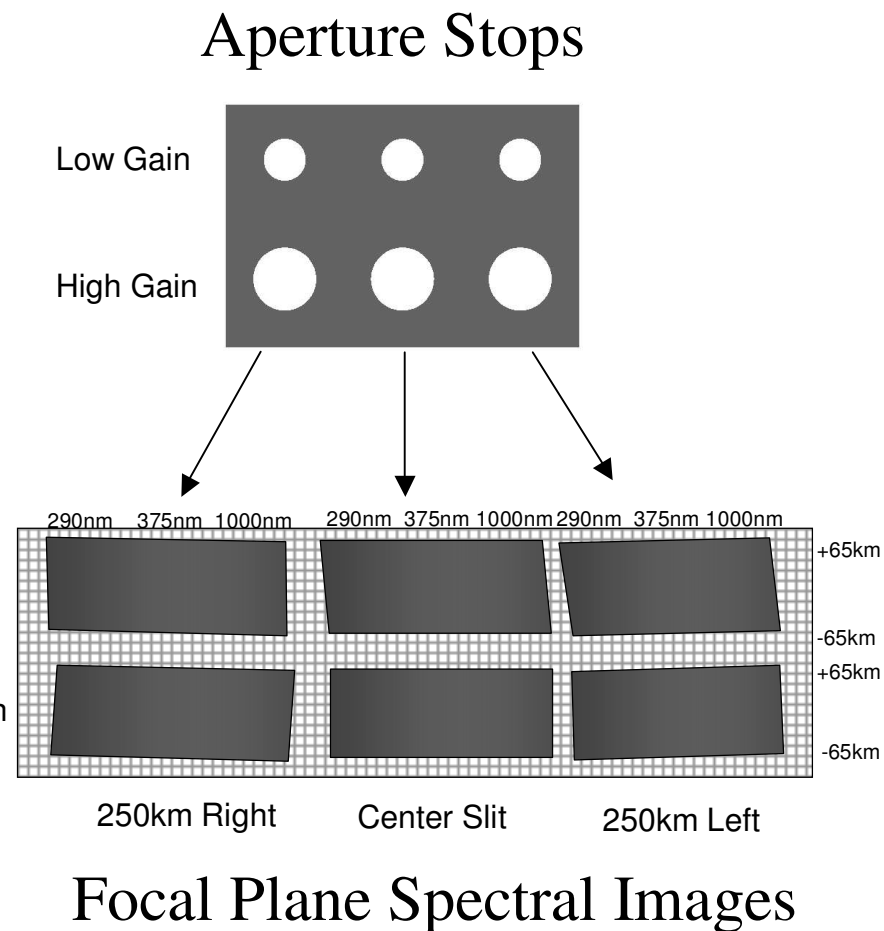 - – **High efficiency**

Dynamic range covered with multiple images and integration times.

- **Cross-track samples obtained with 3 separate apertures/telescopes.**

- **Scene dynamic range coverage.**
  - **2 Separate apertures in each telescope produce 2 optical gains.**
  - **2 Interleaved integration times produce 2 electronic gain levels.**
  - **Total of 4 gain levels provide coverage of scene dynamic range with good SNR.**
    - ◆ **High-Gain long integration**
    - ◆ **Low-Gain long integration**
    - ◆ **High-Gain short integration**
    - ◆ **Low-Gain short integration**

- **All six spectra captured with a single focal plane**

Aperture Stops

Low Gain

High Gain

290nm　375nm　1000nm　　290nm　375nm　1000nm　290nm　375nm　1000nm

Low Gain (Dim)

High Gain (Bright)

+65km

-65km

+65km

-65km

250km Right　　　　Center Slit　　　　250km Left

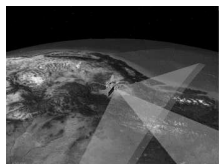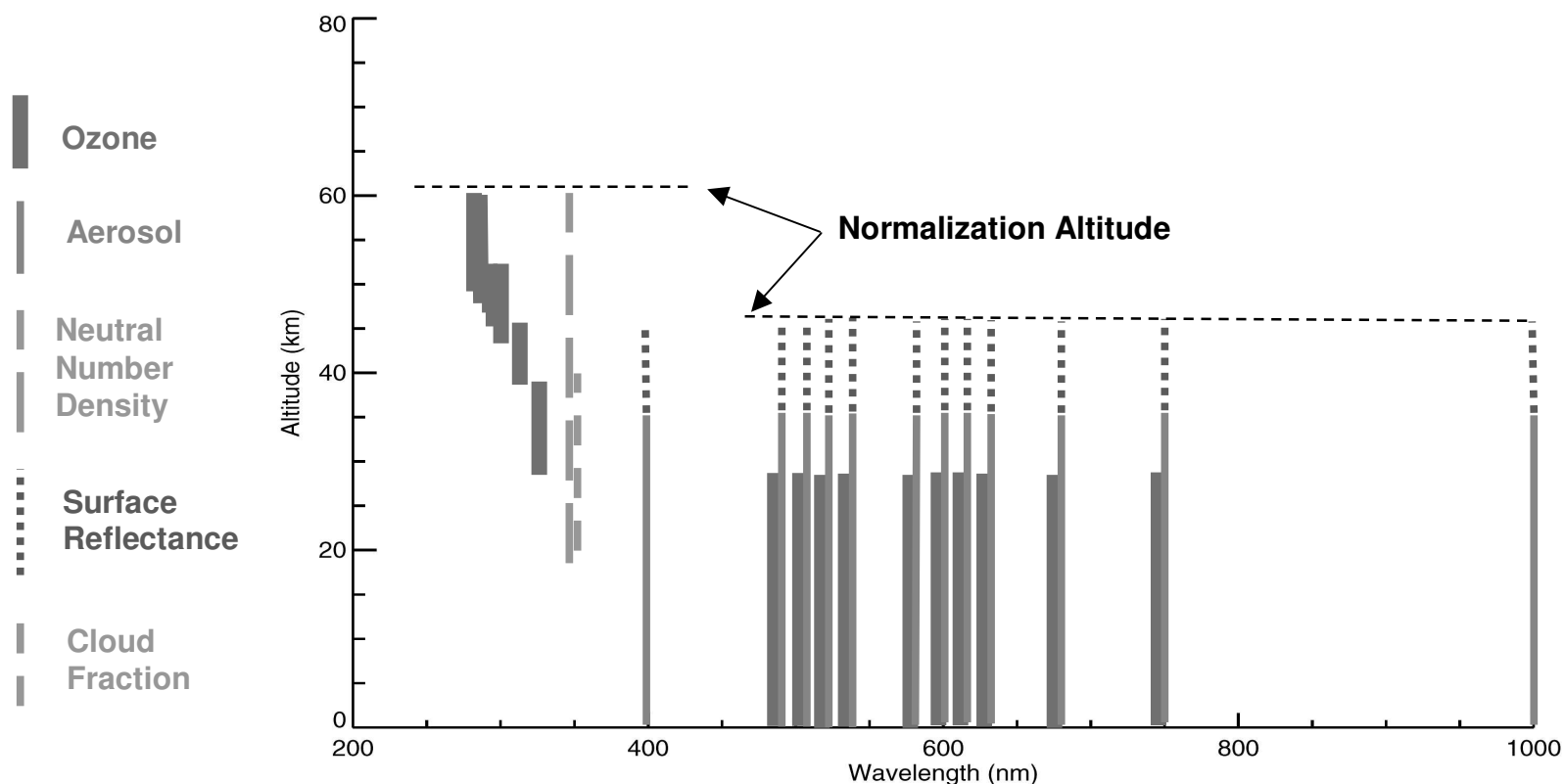Focal Plane Spectral Images

OMPS Limb Sensor Spectral Coverage is 290-1000 nm

- **Middle and near-ultraviolet channels provide coverage from 28 to 60 km**

- **Visible channels including 602 nm provide coverage from tropopause to 28 km**

- **Additional channels between 350 and 1000 nm provide characterization of Rayleigh and aerosol scattering background**
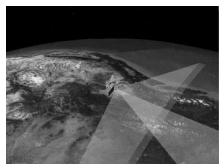
SOLSE/LORE Algorithm Provides Strong Foundation for OMPS Profile Ozone Retrieval

- **Forward model radiative transfer code developed by U. of Arizona (Ben Herman and Dave Flittner)**
  - Multiple scattering solution in a spherical atmosphere
    - ◆ Molecular and aerosol scattering
    - ◆ Ozone absorption
  - Includes polarization
  - Provides high accuracy with minimal computation
- **Inversion code developed by Code 916 and U. of Arizona**
  - Retrieval performed using optimal estimation algorithm
- **Enhancements by OMPS team include:**
  - Additional ozone channels
  - Aerosol extinction profile retrievals at non-ozone-absorbing wavelengths
  - Bulk neutral density retrievals
  - Effective surface reflectance and cloud fraction retrievals
  - Nadir profiler measurements used as first guess and for altitude registration of the limb profile measurement

OMPS Includes an Algorithm That Uses Data from the Cross-track Infrared Sounder (CrIS) to Obtain Ozone Column Measurements

- **CrIS band 1 (635 - 1095 cm^{-1}) contains temperature, ozone, and surface information, along with some information about H$_2$O**

- **CrIS EDRs (Temperature, pressure and water vapor profiles) are used in conjunction with CrIS SDRs (950 - 1095 cm^{-1}) to retrieve ozone**

- **Emphasis is on polar night, measurements in the South Atlantic Anomaly (SAA)**
  - **Retrievals in SAA will help to validate performance of nadir total column CCD and, hence, retrievals in this area**
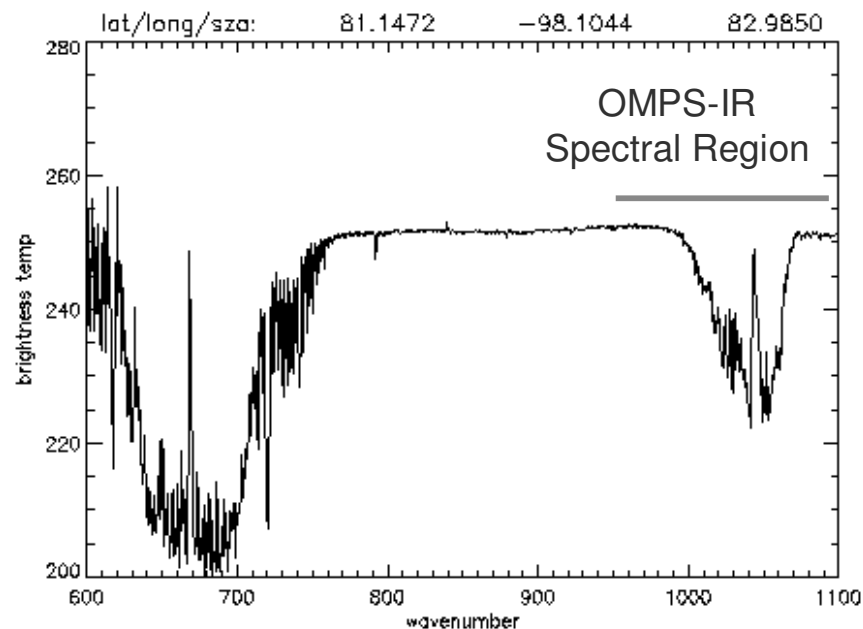
IMG Data from Mar/Apr 1997
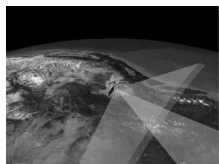**Courtesy of Ryoichi Imasu (University of Tokyo)**
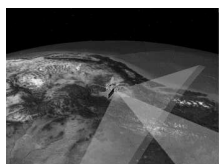
Other Products Also Possible from OMPS
Nadir Sensors

Product	Spectral Range (nm)	Comment
H_2CO	336-357	Can detect down to 1.3×10^{15} mol / cm^2
BrO	345-369	Can detect
OClO	354-383	Can detect in polar votex
NO_2	340-380	Can detect from biomass burning, urban pollution
SO_2	313-321	Detection better than GOME

Conclusion

- **Ozone Mapping and Profiler Suite (OMPS) will provide:**
  - **Global mapping of total column every 24 hours**
  - **High-vertical-resolution limb ozone profiles**
  - **Along-track vertical profile, continuing SBUV-SBUV/2 record**
- **Engineering Demonstration Units built and tested**
- **First flight will be on NPP in 2006**
- **First NPOESS flight planned for 2011**